San Juan Basin Hydrology Model
Draft Operating Criteria - 8/19/2002

Background

This document specifies the operating criteria for the third generation San Juan Basin Hydrology Model (SJBHM). This model is used to support long-term operation and planning decisions in the San Juan River Basin. Primary uses of the model are to evaluate operating scenarios related to meeting San Juan River Basin Recovery Implementation Program (SJRIP) flow recommendations and to evaluate the impact of proposed projects. This document provides a brief overview of the flow recommendations, a brief overview of existing operating criteria, and an outline of potential operating criteria for the third generation model.

The SJRIP flow recommendations consist of two basic components: 1. baseflows to provide sufficient aquatic habitat for species recovery and 2. flushing flows to create and maintain habitat over time. The baseflow is a minimum flow that should be maintained in the San Juan River at reference stream gages within the critical habitat. The flushing flows are provided by making releases during spring runoff with specified hydrographs whose characteristics are dependent upon available flow. The flows at the reference gage (Four corners, NM) are statistically evaluated to determine if flow recommendations are being met. The flow recommendations for spring peak flows are determined to be met when the maximum return periods and recurrence frequencies for specified flows and durations over the period of hydrologic record are met. Tables 1 and 2 summarize the SJRIP flushing flow recommendations.

Table 1. Maximum Return Period Between Events

Flow Criteria & Min Duration	Max. Return Period - yrs
9700 cfs for 5-days	10
7760 cfs for 10-days	6
4850 cfs for 21-days	4
2450 cfs for 10-days	2

Table 2. Flow Duration Statistics

Duration	Threshold Discharge			
	>10,000	>8,000	>5,000	>2,500
	Average Frequency			
1 days	30.0%	40.0%	65.0%	90.0%
5 days	20.0%	35.0%	60.0%	82.0%
10 days	10.0%	33.0%	58.0%	80.0%
15 days	5.0%	30.0%	55.0%	70.0%
20 days		20.0%		65.0%
21 days			50.0%	
30 days		10.0%	40.0%	60.0%
40 days			30.0%	50.0%
50 days			20.0%	45.0%
60 days			15.0%	40.0%
80 days			5.0%	25.0%

The basic approach to meeting the recommended flows is to specify basic operating criteria for the hydrologic model and evaluate the output of the model to determine if the statistics are met.

First and Second Generation Operating Criteria

The first and second generation models used the following basic operating criteria:

1. Operate San Juan Chama by project operating criteria.
2. Operate Animas La Plata by project operating criteria.
3. Operate all other projects to emulate historical operations.
4. Operate Navajo Reservoir to meet historical operating criteria as well as meet flow recommendations.

Navajo Reservoir is the primary facility that is managed to meet flow recommendations. The second generation model enabled ALP to stop pumping in June when a flushing release has not occurred for the past two years and a larger release is not occurring this year. Some additional mitigation options were explored for ALP but both were found unusable. The complete set of operating constraints for Navajo Reservoir are:

1. Maximum release of 5000 cfs.
2. Minimum release of 250 cfs.
3. Minimum elevation of 5985 during the non-irrigation season.
4. Minimum elevation of 5990 during the irrigation season.
5. Provide NIIP demands.
6. Provide downstream demands.
7. Meet COE flood control restrictions.
8. Release surplus water not needed for other uses during runoff season.
9. Release surplus water to meet end of December target space after runoff season.
10. Meet flow recommendations baseflow specification.

A set of criteria were developed to make flushing releases based upon water supply and previous releases. This is referred to as the decision tree and is shown on Figure 1. The following definitions and conditions are used in the decision tree diagram:

1. available water – water that is not committed to other uses
2. spill – water in excess of storage capacity that must be released to prevent water flowing over the spillway
3. flow recommendation release hydrograph volumes – specified to provide the desired hydrographs for various levels of water supply
4. previous releases – influence the need to make a release in the current year.

The circled numbers shown at decision points correspond to path numbers that are used to track decisions. The flow recommendation release volumes consist of four basic hydrographs as specified in Table 1. During wet years, more water must be released from Navajo than the flushing release volume to prevent Navajo from spilling. The excess water (spill minus available water) is applied to the nose of the hydrograph while attempting to maintain the basic shape of the hydrograph.

Figure 1. First and Second Generation SJRIP Decision Tree

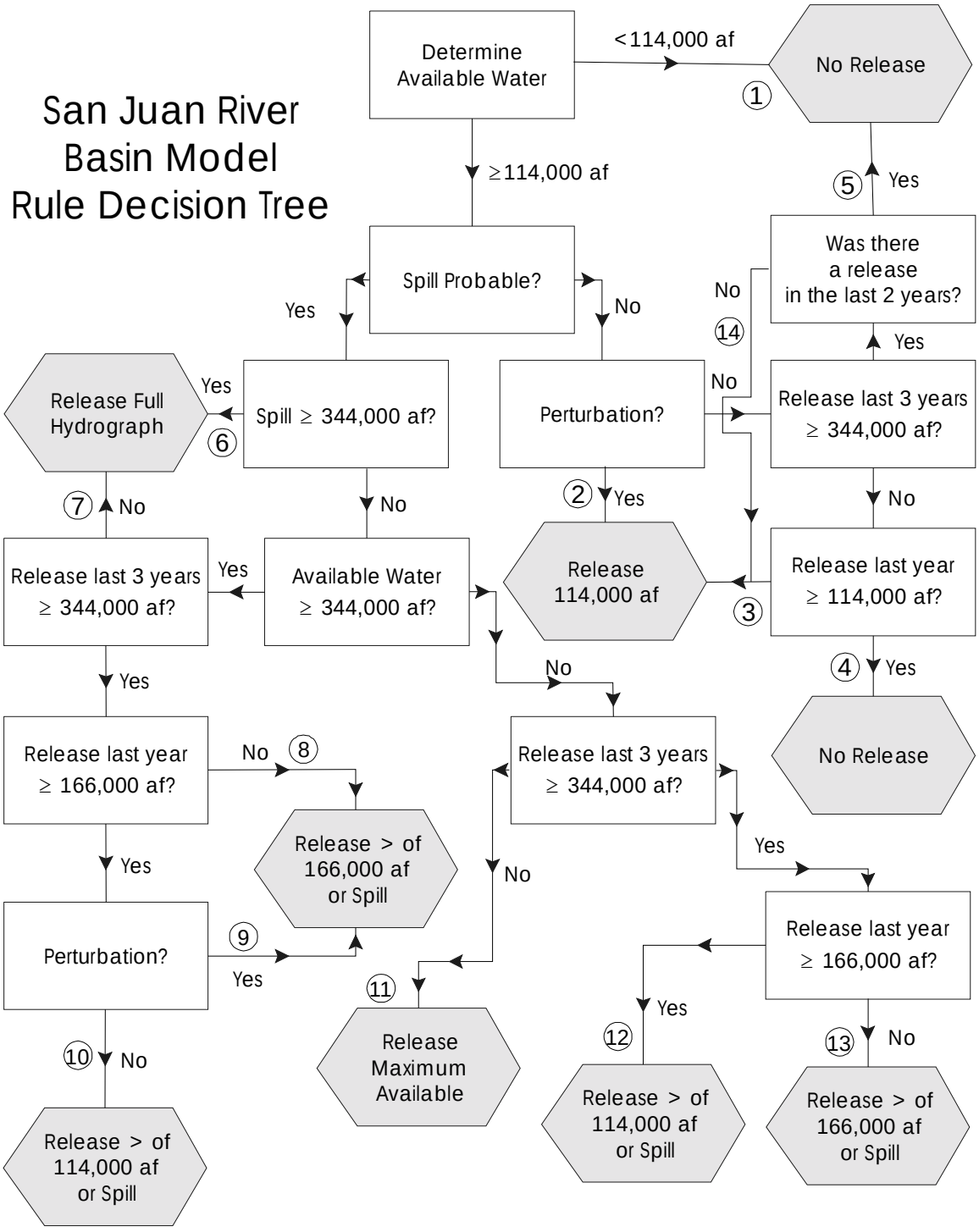

Table 1. Navajo Fish Release Hydrographs

344,000 ac-ft Hydrograph			236,000 ac-ft Hydrograph			166,000 ac-ft Hydrograph			114,000 ac-ft Hydrograph		
CFS	Days	Ac-ft	CFS	Days	Ac-ft	CFS	Days	Ac-ft	CFS	Days	Ac-ft
1,000	7	13,884	1,000	1	1,983	1,000	1	1,983	1,000	1	1,983
2,000	7	27,769	1,500	1	2,975	1,500	1	2,975	1,500	1	2,975
3,000	7	41,653	2,000	1	3,967	2,000	1	3,967	2,000	1	3,967
4,000	7	55,537	2,500	1	4,959	2,500	1	4,959	2,500	1	4,959
5,000	21	208,264	3,000	1	5,950	3,000	1	5,950	3,000	1	5,950
4,500	1	8,926	3,500	1	6,942	3,500	1	6,942	3,500	1	6,942
4,000	2	15,868	4,000	1	7,934	4,000	1	7,934	4,000	1	7,934
3,500	1	6,942	5,000	21	208,264	5,000	13	128,926	5,000	7	69,421
3,000	2	11,901	4,000	1	7,934	4,000	1	7,934	4,000	1	7,934
2,500	2	9,917	3,500	1	6,942	3,500	1	6,942	3,500	1	6,942
2,000	2	7,934	3,000	1	5,950	3,000	1	5,950	3,000	1	5,950
1,500	2	5,950	2,500	1	4,959	2,500	1	4,959	2,500	1	4,959
1,000	2	3,967	2,000	1	3,967	2,000	1	3,967	2,000	1	3,967
			1,500	1	2,975	1,500	1	2,975	1,500	1	2,975
			1,000	1	1,983	1,000	1	1,983	1,000	1	1,983
Total Release	63	418,512		35	277,686		27	198,347		21	138,843
Base Release*	600	74,975		600	41,653		600	32,132		600	24,992
Net Release		343,537			236,033			166,215			113,851
*600 cfs for 63 days			*600 cfs for 35 days			*600 cfs for 27 days			*600 cfs for 21 days		

Limitations of First and Second Generation Model

SJBHM is a RiverWare model that uses RiverWare engineering objects to simulate basin hydrography and facilities, RiverWare data objects to store decision data, and RiverWare Policy Language (RPL) to implement operating criteria using rules. The first and second generation versions of SJBHM were monthly time step models that simulated various daily processes. SJC, ALP, and the flushing release computations are all daily computations within the monthly model. Although daily computations can be done with RPL, engineering objects only fire at the model's time step. Therefore, disaggregation and aggregation issues existed. The most problematic was the flushing release criteria.

The specified flushing release was from Navajo Reservoir. The flow recommendation criteria are evaluated at the Four Corner's gage. Since the model was a monthly model and the flow recommendations are based on daily flow statistics, the daily downstream flow at Four Corner's had, to be estimated. This was accomplished by disaggregating the monthly model output into pseudo-daily values after the model had run to evaluate the results against the flow recommendations. Since the model does not know when certain flow conditions have been met, this information cannot be used for future decisions during the model run. The only historic decision information that was available to the model during the run was the type of previous year's release.

These models also had a computational inefficiency related to application of the excess water to the flushing release. Specifically, the set of possible hydrographs was recomputed every March and every April. These could be specified in a data object as a prescribed hydrograph for a given water supply. These would essentially be sub-paths of the existing paths.

Options Made Possible By Third Generation Daily Decision Model

The third generation SJBHM will be a daily model. This will give the modelers considerably more flexibility in applying the operating criteria in RPL. Furthermore, it will shift disaggregation issues from the model output to the model input, requiring that the disaggregation process be utilized only when there is a change in input data.. In addition, the ability to compute the flow recommendation performance statistics during a model run provides the ability to use these statistics to affect releases during a model run. How this might be accomplished remains to be decided and is the purpose of this document.

A daily model introduces input data issues as noted above. A daily model also affects operations other than the flow recommendation releases. For instance, the COE flood control criteria are based upon a forecast of daily flows. This requires that daily inflows to Navajo Reservoir be known. Forecasts are based upon monthly hydrology and demands and historical forecast error. Historical forecast error is based upon historical forecast unregulated inflow compared to actual historical unregulated inflow. With the daily model, two questions arise: Will monthly forecast be sufficient for a daily model? Should the option of using mid-month forecasts be explored?

The third generation model implementation also suggests a revisit of the criteria evaluation. For instance, only the San Juan Four Corners gage is presently used to compute performance statistics. Would it make sense to use a sampling of gages as is done in the actual operations? Can more creative use of the fall surplus water release be made? Can the final flushing release decision be delayed until mid-May?

Given the above background and historical information, the following operating criteria are proposed for the third generation model.

Third Generation Operating Criteria

The fundamental operating criteria for the third generation SJBHM will remain the same. However, the StateMod baseline model and the RiverWare monthly migration model will be doing some of the work. Emulation of historical operations should be considerably more sophisticated using this system. SJC will be operated in the migration model. The daily decision model will consist only of those nodes necessary to operate ALP and Navajo Reservoir. The monthly model will only have to be operated when hydrology is revised or when baseline depletions are revised. Disaggregated daily and some monthly data (forecasts) will be transported between the migration model and the daily decision model. (See ThirdGenModelAndDataDevSummary for additional information on the modeling system.)

ALP will be operated in the daily decision model. Its operation will remain the same but have to be reimplemented in RPL for the daily time step. Initially, the overall operating criteria for Navajo Reservoir will remain the same. The flushing release computations will be adjusted to take advantage of the daily time step and enhanced RiverWare features. It is also highly recommended that the daily COE flood control criteria be implemented. RPL code already exists to do this but daily inflows to Navajo would have to be developed.

Due to limited resources to implement the new model, it is highly recommended that the basic process of using a decision tree not be abandoned. This would also facilitate incremental implementation, debugging, and decision tracking. As the model is debugged, calibrated and verified, adjustments to the operating criteria can be made. Initially, the following adjustment to the release decisions are recommended:

1. In the first and second generation models, one of four discrete hydrographs are used if a flushing release is required and water is available in Navajo. These were shown in Table 1 and total 114000, 166000, 236000 and 344000 ac-ft above a 600 cfs baseflow. If a release of 114,001 ac-ft is called for, the model would release the second hydrograph of 166,000 ac-ft. This results in an over release of 52,000 ac-ft. In the third generation model, this problem will be eliminated, by releasing the actual volume that is required. In the example given, 114,001 ac-ft or a close approximation (see item 2 below) would be released instead of 166,000.

2. All release hydrograph possibilities will be prescribed by storage in data objects to reduce computations. The decision tree will determine the basic flushing release volume but a table will determine the actual shape of the hydrograph based upon excess water. This would be called a sub-path to the main decision path.

3. A better algorithm for timing releases will be investigated that includes an analysis of weather data to provide a simulation of forecasting the timing of the Animas runoff to better match the peak release with the peak runoff from the Animas. Presently, the release is centered on the same date each year.

4. The decision tree will be adjusted to incorporate evaluation of return period statistics during the model run. For instance, if the 9700 cfs for 5 days event has occurred within the required 10 years, the decision tree would not necessarily force a release. Conversely, if a condition that was required every 10 years had not occurred for 7 or 8 years, an attempt to conserve a release in a given year may be made to allow making a larger release in a subsequent year. The exact

nature of these rules must be developed based on trial and error operation, but the concept is to better target the desired results when determining the releases. Again, these would probably be sub-paths of the main decision path.

5. Presently, once a release begins, it cannot be adjusted. In years where the forecast runoff is not met, the model over-released. With the daily timestep, reservoir inflow will be checked against forecast, with the potential of shortening the duration of the peak when the inflow falls short.

6. Base releases will utilize a mix of down-stream gages and implement the present flow recommendations as written, utililizing a running mean.

7. With and integrated daily timestep model, it may be possible to include operation of Ridges Basin Reservoir in meeting flow recommendations. The possibility of joint operation of Navajo and Ridges Basin Reservoir will be explored.

8. The performance statistics will be evaluated using the same criteria as actual operations are using.

Status of San Juan Basin Hydrology Model (SJBHM)
8/16/2002

Data Development

Historic power depletions and diversion were provided by NMISC for review. Data are being migrated to Reclamation and StateMod formats. NMSIC also provide default irrigation and non-irrigation efficiencies.

CWCB is updating their historic time series database and acreages. Both tasks should be completed by the end of August. SLC has provided Reclamation's reservoir data but some data are missing. Reclamation will provide New Mexico, Utah, and Arizona as it becomes available.

Arizona and Utah data are being reviewed for the Colorado basin natural flow data set, which is concurrently being updated. These data will not be available until calendar year 2003. Since Arizona and Utah depletions are relatively insignificant to SJBHM, we have requested some provisional data by end of August that will be used for SJBHM. Utah and Arizona data will be updated in SJBHM at an appropriate juncture.

Development of historic and baseline NIIP depletions and operations are nearing completion.

Additional work was done on disaggregation data and procedures.

Model Development

The mainstem reconfiguration is essentially completed unless NMSIC provides additional comment. CWCB is rebuilding StateMod model. Natural flow and baseline computations will need non-Colorado data when they are available.

Initial draft of third generation Navajo operating criteria was formulated.

The ability to user provided frost dates was added to the Blaney-Criddle model. Blaney-Criddle input files and depletion spreadsheets are complete except for final New Mexico input data.

Evolution of San Juan Chama objects and rules for use in the migration model is completed. Forecast computations for the migration model are nearly complete.

RiverWare with additional water user capabilities was obtained and tested.

Outstanding Data Needs

As noted above, most of the non-New Mexico data processing should be completed by end of August. Final historic New Mexico acreages, cropping patterns, and most non-irrigation data remain to be provided by NMISC. In addition, baseline acreages, cropping patterns, and non-irrigation depletions need to be provided by NMISC.

Development of daily natural gains cannot be completed until the revised natural flows are available. A RiverWare model will be cloned from the decision model to support this activity.

Development of outlet works and spillways stage discharge tables for non-Reclamation reservoirs.

Development of RiverWare formatted daily return flow patterns and evaporation coefficients.

Develop streamflow lagging (routing) data for daily decision model.

Outstanding Modeling Activities

Conversion of existing rules to use compiled RiverWare functions in lieu of user defined functions that may be available in latest RiverWare.

Populate, validate, and debug migration model.

Creation of daily version of ALP rules for new decision model.

Testing of Navajo operating options and completion of operating criteria and rules based upon tests results.